Geophysical Research Abstracts
Vol. 16, EGU2014-11112, 2014
EGU General Assembly 2014

Dynamics of lithospheric thinning and melting by edge-driven convection

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We have studied the dynamics of the mantle melting and lithosphere erosion during edge-driven convection (EDC), a process that takes place at locations of pronounced lithosphere thickness gradients (e.g. ocean-continent boundary, craton edge). EDC can be driven by either the cratonic lithosphere cooling the asthenosphere under the thinner lithosphere next to it, thus causing downwelling (EDC sensu stricto), or by upwelling of the hotter asthenosphere from below the craton along the edge (continental insulation, causing secondary EDC). EDC has been shown by previous studies to be, for example, a viable mechanism for flood basalt formation (King and Anderson 1995) and for the recent volcanism around the edges of the Colorado plateau (van Wijk et al. 2010).

Recently, EDC has been suggested to explain the thinning of the lithosphere, consequent high topography, and Cenozoic volcanism at the Moroccan Atlas mountains (Missenard and Cadoux, 2012). In this study, we test this hypothesis. Many of the previous studies on EDC do not show or discuss the lithospheric thinning by EDC in detail. Results from our numerical mantle convection models with hydrous melting parametrization and varying mantle potential temperatures, water contents and rheological activation energies, show that varying amounts (15-45 km) of lithospheric erosion due to EDC is possible. Different amounts of melts can be produced, including production rates similar to those observed at the Maroccon Atlas mountains (0.5 to 30 m/Myr). However, the amount of lithospheric thinning is not a major control in the amount of volcanism, but instead it is more strongly controlled by the overall thickness of the lithosphere. EDC can lead to significant dynamic topography, where the down- and upwellings of the convection cell produce topographic low and high, respectively, in order of a few meters.

More vigorous convection caused by the EDC results in increased heat flow through the lithosphere, and thus for Moho temperature values, having possible implications for the lower crust melting. Mantle melting due to EDC has a pulsating nature, periods of which vary from 10 to 30 Myrs, and is controlled mainly by the effective viscosity of the mantle. These periods correspond to the length of quiet periods between magmatic pulses observed at the Atlas mountains, a feature that was previously suggested to be due to change in African plate velocity. A similar quiet period is present at the Colorado plateau volcanism. Additionally, our models show that the two competing mechanisms for EDC (EDC sensu stricto and contintental insulation) may occur simultaneously, for the upwelling caused by the continental insulation forms a convection cell, smaller in size but otherwise similar to the EDC sensu stricto convection cell, next to the edge.